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AIR POLLUTION EMISSIONS AND CONTROL TECHNOLOGY.
SECONDARY LEAD SMELTER AND ALLIED INDUSTRIES

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ABSTRACT

This report evaluates the contribution to air pollution by the Canadian secondary lead smelter and allied industries in 1970.

Secondary lead manufacturing is defined and Canadian operations are reviewed with respect to size, location, products and emissions. Control technology is discussed and its potential for emission reduction is estimated.

The report serves to provide background information for use in the establishment of National Emission Standard Regulations for the Canadian secondary lead smelting industry.

RÉSUMÉ

Le présent rapport est une évaluation de l'apport de l'industrie du plomb de seconde fusion et des industries connexes à la pollution atmosphérique, en 1970.

On y définit la récupération du plomb, et on y traite des installations canadiennes selon leur importance, leur emplacement, leur production et leurs émissions, ainsi que des techniques antipollution. Les possibilités de ces dernières pour la réduction des émissions sont évaluées.

Le rapport contient les renseignements de base qui ont servi à l'élaboration du Règlement relatif aux normes nationales d'émissions des fonderies de plomb de seconde fusion.

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1 INTRODUCTION

1.1 General

The Department of the Environment consulted with the Department of National Health and Welfare on the subject of the environmental toxicity of airborne lead. As a result, the Department of National Health and Welfare recommended the implementation of measures designed to control emissions of lead from major sources.

1.2 Scope

This study pertains to air pollution control in the metallurgical secondary lead industry in Canada. Size and location of plants, products, relative importance of the industry to the Canadian economy, and process and emission control technology are discussed. Results from a national emission inventory (1970) as well as emission data from surveys carried out in the United States are included.

1.3 Purpose

The primary purpose of this report is to provide the necessary technical information for the preparation of effective national emission regulations for the Canadian metallurgical secondary lead industry. For this purpose, a secondary lead plant is defined as a stationary source, subject to both national emission regulations and guidelines that may be published by the Governor in Council as required by the Clean Air Act of 1971.

A secondary purpose of this report is to assist in the development of federal briefs, state-of-the-art reviews, and other documents related to air pollution emanating from secondary lead plants.

1.4 Information Sources

A computer search of the literature was conducted by the National Science Library and the Environmental Protection Agency (EPA) of the United States. Copies of original papers were acquired through the reference section of the library of the Department of the Environment. EPA recently promulgated emission standards for the secondary lead industry, and background reports on several plants were available, including results of actual emission testing from specific processes. The great similarity between secondary lead operations in the United States and Canada allowed the application of this information to Canadian operations. Considerable background and bibliographic information was obtained from an Air Pollution Control Directorate report entitled "National Inventory of Sources and Emissions of Lead (1970)" (1). Articles issued in the most recent trade literature were reviewed and information was also obtained from a publication of the Industrial Gas Cleaning Institute (2).

Contacts were established with provincial regulatory agencies, members of the National Research Council of Canada and the following Departments of the Federal Government: Energy, Mines and Resources; Industry, Trade and Commerce; and Statistics Canada.

2 INDUSTRY DESCRIPTION

2.1 Introduction

Excellent malleability and corrosion resistance are among the unique chemical and physical properties of lead which have resulted in a wide variety of industrial applications, summarized as follows:

Characteristics	Use
Corrosion resistant	Construction, water pipes, chemical equipment, electrical cable sheathing, storage batteries
Soft, malleable	Ammunition, packaging (collapsible tubes)
High density	Ballast, counter weights, X-ray shielding, acoustic insulation
Frictional properties	Bearings, machinable alloys

2.2 Definition of Secondary Lead Manufacturing

Secondary lead manufacturing is defined as any metallurgical process that remelts or refines lead ingots, or lead-containing scrap of various types and produces metallic or compound lead which is further used in the manufacturing process. To achieve this end various furnaces are employed including blast, reverberatory and kettle-type furnaces. Processes which use some or all of these furnace types include storage battery production, lead compound manufacture, and metal fabricating.

2.3 Size and Location

2.3.1 Lead Recovery Plants. Six major companies operate lead recovery plants in Canada, three of which are located in the Toronto area. Other plants are located in Montreal, Winnipeg, Calgary, and Vancouver. Most recently published individual plant production figures for 1970 totalled 41 024 tons, as shown in Table 1. These figures are based on questionnaire replies from three major lead recovery companies operating seven plants in Canada and therefore do not include all secondary lead production in Canada. (1)

2.3.2 Storage Battery Plants. There are 25 battery plants operating in Canada. Table 2 lists the location and number of Canadian battery manufacturers together with their relative size, in terms of shipment value (1).

TABLE 1 SECONDARY LEAD PRODUCTION IN CANADA, 1970

Location	Production (tons)	Process*
Montreal, Quebec	4 120	BF, MK
Toronto, Ontario	5 785	BF, MK
(3 plants)	15 000	RF, MK
	12 000	RF, BF, MK
Winnipeg, Manitoba	2 191	RF, MK
Calgary, Alberta	1 804	RF, MK
Vancouver, British Columbia	124	MK
TOTAL	41 024	

*Abbreviations: BF, Blast furnace; RF, reverberatory furnace, MK, melting kettle.

2.3.3 Lead Compound Manufacture. The second largest use of lead in Canada is in the manufacture of lead compounds. The principal compounds produced include alkyl lead gasoline additive chemicals and lead oxides.

In 1970, approximately 17 800 tons of lead, or 70% of all lead in compound form, were consumed as alkyl lead gasoline additives (1). These compounds, tetraethyl and tetramethyl lead, have been added to gasoline in order to raise the octane number and prevent spontaneous fuel ignition or 'knocking'. There are two plants in Canada that produce anti-knock compounds; both are located in Ontario.

Lead oxide (PbO), or litharge, is a reddish-brown powder used by a variety of consumers including the storage battery, paint, and ceramic industries. Approximately 9200 tons of litharge were produced in Canada in 1970 by two major plants located in Ontario (1). This figure does not include the lead oxide produced by battery manufacturers for their own use.

2.4 Products

Table 3 summarizes the consumption of primary and secondary lead by Canadian industries in 1970. The major use of lead in Canada is in the manufacture of lead storage batteries for automobiles and trucks. In 1970, 40 472 tons of lead were used for battery production. Approximately 50% of this total came from secondary smelting plants.

TABLE 2 CANADIAN BATTERY MANUFACTURERS, 1970

Province	Number of plants	Value of shipments	
		Thousands of dollars	Percent of total
Nova Scotia	1	2 772	4.3
Quebec	3	8 432	13.3
Ontario	11	39 340	61.7
Manitoba	2	5 542	8.6
Alberta	2	5 542	8.6
British Columbia	6	2 242	3.5
TOTAL	25	63 870	100.0

The second major use of lead in Canada, the manufacture of lead compounds, amounted to 25 498 tons in 1970.

Other uses include the manufacture of cable sheathing, ammunition, collapsible tubes, caulking materials, corrosive-liquid containers, lead base babbitts and plumbing equipment. Lead is also used in the production of automotive wheel weights, ship ballast, roofing, and sprayed lead coatings. Relatively new applications of lead are leaded porcelain enamel and radiation shielding.

One of the most useful applications of lead is the production of lead alloys, which combine the corrosion-resistant properties of lead and the physical properties of the alloy metal.

Table 4 is a breakdown of the major alloys and their usage.

The most common grades of lead produced by the secondary metals industry are classified as 'hard', 'semi-soft', and 'soft' (2). Hard lead is the principal product of the blast furnace and, depending on the raw materials added to the furnace, may be composed of 5-12% antimony, 0.2-0.6% arsenic or 0.5-1.2% tin, together with minor quantities of copper and nickel. Further refining in a reverberatory furnace will produce semi-soft lead which may contain varying amounts of antimony (0.3-0.4%) and copper (0.05%). Soft lead, from which most alloying elements or impurities have been removed, is produced in a kettle furnace and has a typical lead composition of 99.97%.

TABLE 3 LEAD CONSUMPTION BY CANADIAN INDUSTRY, 1970 (3)

Industry	Lead consumption (tons)		Total	% Consumption
	Primary	Secondary ³		
Battery manufacture	20 273	20 199	40 472	43.2
Lead compound manufacture	22 112	3 386 ¹	25 498	27.3
Semifinished products ²	8 570	479	9 049	9.7
Solders	2 527	2 977	5 504	5.9
Alloys (babbits, type etc.)	268	2 875	3 143	3.4
Cable sheathing	2 296	770 ¹	3 066	3.3
Antimony-lead	1 412	962 ¹	2 374	2.5
Copper alloys	318	47 ¹	365	0.4
Other uses	2 367	1 599	3 966	4.3
TOTAL	60 143	33 294	93 437	100.0

¹ Secondary lead use by these industries was available only for 1967. Use in 1970 has been estimated by applying the percentages of primary versus secondary lead calculated from 1967 data. A total of 5165 tons of secondary lead was involved in these estimates.

² Includes pipe, sheets, traps, bends, foil, caulking blocks, ammunition, tubes, etc.

³ Most secondary lead recovery is from products such as battery plates, cable sheathing, printing type metal and various slags and drosses.

2.5 Relative Importance

The lead industry, was ranked fifth in Canada, in 1970, in terms of tonnage consumed, following only steel, aluminum, copper and zinc. Secondary lead represented approximately one third of the total lead consumed (Table 3).

TABLE 4 MAJOR LEAD ALLOYS AND THEIR USAGE

Alloy	Composition range of alloying element	Product
Antimony-lead	1-10% antimony	Storage batteries and cable coverings
Calcium-lead	0.07% calcium	Industrial storage batteries
Copper-lead	20-40% lead	Bearings and bushings
Copper-zinc-lead (brass)	0.5-3% lead	Bearings and bushings
Lead-silver	1.5-5% silver	Solders, chemical electrodes
Tin-lead*	38-98% lead	Solders, protective coatings on copper and steel (terne metals)

*When alloyed with antimony for bearings, printing type, and casting metals.

3 INDUSTRIAL PROCESSES

3.1 General

Secondary lead is produced in blast (cupola) or reverberatory furnaces at temperatures of about 2300 °F. Final refining is usually done in reverberatory or pot-type furnaces at temperatures of 1290-1650 °F. The four main steps in processing secondary lead are: sorting and preparing the alloy scrap according to size and alloy groups; smelting in blast or reverberatory furnaces; refining in pots or kettles and casting to ingots or final shapes. A principal product of the blast furnace is antimonial or 'hard' lead which can be cast directly into large blocks of varying weights. Typical blocks weighing 2000 pounds are used as ballast and counter weights in the shipping industry. Final processing or purification of the metal involves the addition of chemical compounds to either reverberatory or pot-type furnaces. These form drosses which usually float on the molten metal surface and can be skimmed, through a furnace door, directly into skim buckets outside the furnace. Drosses contain impurities such as copper, nickel and antimony. Further alloying can then be carried out if desired. Some scrap, such as cable sheathing, is pure enough to be added directly to a melting pot without further refining.

3.2 Blast Furnace (Cupola) Operation

A lead blast furnace is a vertical furnace with a circular cross section. The lower section of the furnace is water cooled while the upper section consists of refractory material. A process flow diagram for a typical lead cupola, including pollution control equipment, is shown in Figure 1. Air is injected through pipes or tuyeres near the bottom of the furnace and combustion of coke provides the heat necessary for melting and for the reduction reaction with the lead oxide. Raw materials are added through the charging door near the top of the cupola and molten lead is tapped off at the bottom. A typical raw material charge is composed of lead dross or other forms of lead oxide, coke, limestone, scrap iron and rerun slag. The cupola's function is to reduce oxidized metal. As the production cycle continues, the limestone and iron form a slag that helps prevent oxidation. The slag is tapped periodically while the flow of lead from the taphole at the base is continuous. The process is semi-continuous; the charge being added over a 2-day period and the product withdrawn almost continuously.

A molten metal level is maintained at the bottom of the cupola, above which a mixed mass of charge solids is contacted with air to burn the fuel, reduce the lead oxide, and melt the product. Relatively high temperatures are reached in this section, but the gases cool as they pass upward through the fresh charge at the top of the mass.

Coke is added with the charge or in alternate loads at the charging door. It is oxidized with blast air furnished by an air compressor to the tuyeres at the bottom of the furnace. Gas flow is usually far in excess of blast-air flow because of infiltration of air at the charge door level.

The charge doors are usually designed to accommodate addition of charge materials by a bucket which is swung into the cupola and dumped. Other charging methods include conveyors on chute feeders. In the case of bucket feed, the charge doors must be large and are frequently left open or removed altogether. This allows a very high rate of air infiltration into the cupola. When air pollution equipment is installed, it is necessary to limit this infiltration to minimize the size requirement and operating cost.

Torches or gas burners are often installed in the cupola, directly above the charging door, to burn carbon monoxide (CO). This afterburner section must have some air seepage to provide for burning the CO, but is costly to operate without good sealing at the charge doors.

The composition of a typical lead cupola charge is shown in Table 5. This table also gives a rough measure of the feed rates for a 25 ton/day cupola (2).

Because the blast furnace is not efficient in retaining molten metal, it cannot be used for purification. The scrap, therefore, is usually charged in reverberatory or pot furnaces for melting and purification.

3.3 Reverberatory Furnace Operation

A reverberatory furnace is a long, rectangular, refractory-lined structure with an arched roof and a burner located at one end. Fuel is a fossil type - pulverized coal, oil or natural gas - and is burned

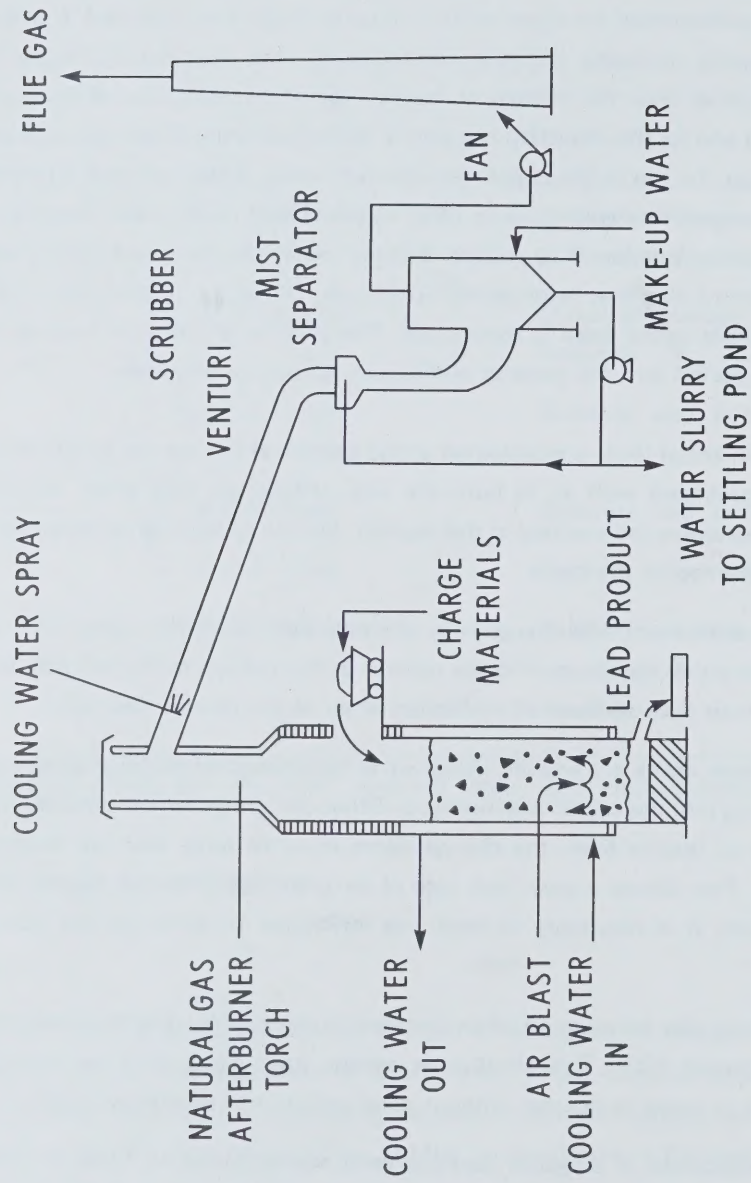


FIGURE 1 PROCESS FLOW SKETCH OF LEAD BLAST FURNACE OR CUPOLA

TABLE 5 TYPICAL COMPOSITION OF LEAD CUPOLA CHARGE (25 TONS/DAY)

Component		Weight (% of total)	lb/hr average
Dross			
(15%)	Metallic lead	82.5	2200
	Pb		
	Sb		
	Sn		
(85%)	Metal oxides		
	PbO		
	SbO		
	SnO		
Rerun slag		4.5	120
Scrap iron		4.5	120
Limestone		3.0	80
Coke		5.5	150
TOTAL		100.0	2670

separately from the metal being processed. A large part of the heat in the combustion gas radiates directly to the charge lying on the hearth below. At the same time a substantial amount radiates to the furnace roof and walls, and is reflected down to the charge - it 'reverberates' in the furnace. The hearth slopes slightly towards the rear of the furnace to allow for continuous tapping of the molten lead. A schematic diagram of a reverberatory furnace including air pollution devices is shown in Figure 2. Rotary or tube-type reverberatory furnaces are used in smaller operations. Rotary furnaces are tapped periodically from ports which are sealed during rotation and firing.

Reverberatory furnaces are used in a number of ways in the processing of lead scrap to lead ingots. Some of these uses are: burnout, sweating, melting and purification. The furnace charge may consist of automobile storage batteries; lead oxides or drosses and skim; lead-sheathed cables; aircraft or ship ballast weights; or other miscellaneous, lead-bearing materials.

3.3.1 Burnout. The burnout operation is not strictly a smelting process but involves the incineration of materials which may be present in scrap metal such as plastics, rubber insulation, wood, paper and other combustibles. Burnout may also involve the decomposition of halogen-containing plastic

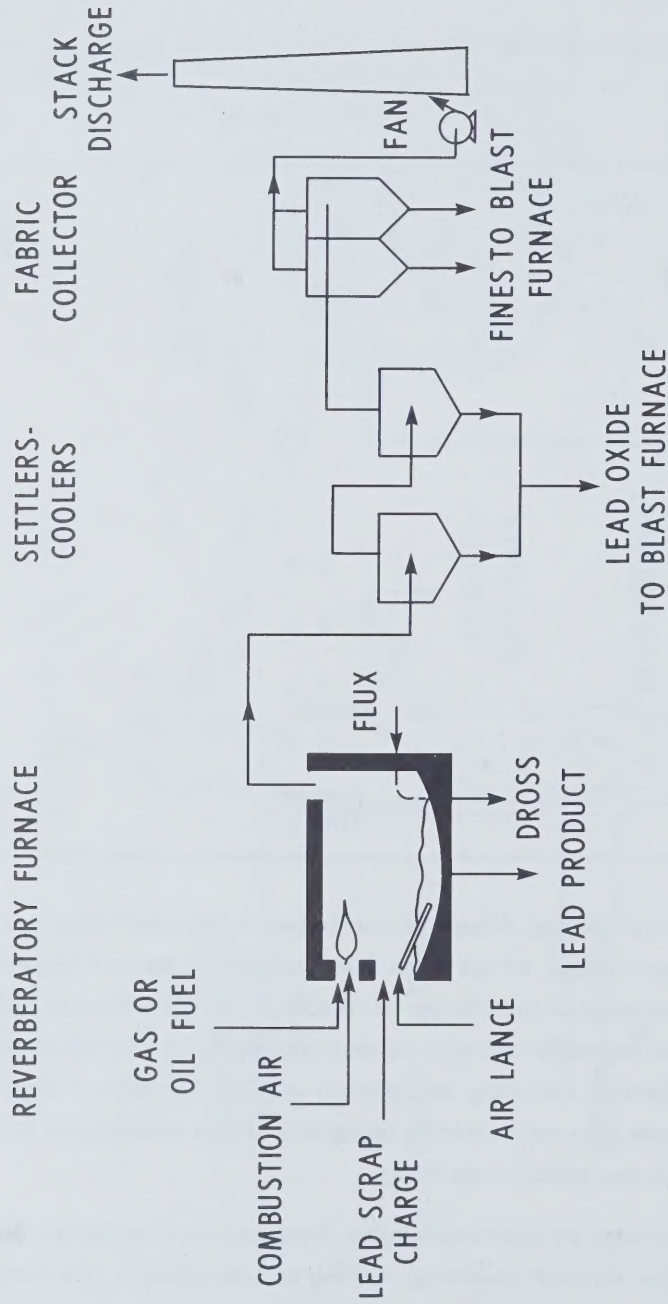


FIGURE 2 PROCESS FLOW SKETCH FOR LEAD REVERBERATORY FURNACE

materials such as polyvinyl chloride wire insulation which releases halogen acids when burned. These are toxic and may also produce objectionable odours.

3.3.2 *Sweating.* The reverberatory furnace is used for the separation of molten lead from various types of scrap containing both metallic and non-metallic impurities. This is referred to by the industry as 'sweating' the melting of the low-melting-point constituent from the charge. This operation normally takes place at about 650 °F.

A typical sweating heat involves charging scrap to the furnace hearth and gradually heating the scrap to a temperature slightly above the melting point of the metal to be separated. As the metal melts from the scrap, it is tapped into ingots. Fresh charge is continuously added until all available scrap is depleted or the heat is terminated. The unmelted scrap must be periodically raked from the hearth for further disposal or sale.

3.3.3 *Melting.* Reverberatory furnaces may be used to melt lead pigs or ingots for casting. This process is more commonly carried out in indirectly heated furnaces such as electric or gas-fired crucibles.

3.3.4 *Purification.* The major use of reverberatory furnaces in secondary lead processing, involves the purification of lead by removal of impurities such as iron, arsenic, antimony and tin. The furnace may be charged continuously with molten metal from the cupola. In this case, air-blowing to oxidize metal impurities, is either intermittent or continuous. The metal dross is removed by slagging and the molten lead is removed by tapping or casting into moulds on an intermittent basis.

Solid lead scrap may also be charged continuously to the reverberatory furnace. Material can be hand-fed through charging doors or fed continuously on conveyors. Here again, air-blowing and drossing can be either intermittent or continuous, with periodic casting.

Although the melting point of pure lead is 625 °F, temperatures exceeding 2000 °F are used for the purification of lead. These higher temperatures are required to bring about a reaction between the metallic impurities and the oxygen sparged into the metal bath. If lead oxide drosses are added to the charge, it is necessary to add a reducing agent such as granular carbon which reduces lead oxide to metallic lead.

It should be mentioned that reverberatory furnaces can be employed for the same purposes as a blast furnace and refining unit with reduction of lead oxides carried out prior to removal of impurities. It is, therefore, not uncommon to carry out the reduction, burnout, sweating and smelting operations sequentially in the same reverberatory furnace.

3.4 Pot and Kettle Furnace Operation

Pot and kettle furnaces are used for remelting, alloying and refining (4). Remelting is usually done in small pot furnaces and the materials charged are most often alloys in ingot form. The pots used in the secondary lead industry range in capacity from 1-50 tons and most are gas fired.

Alloying normally begins with a metal lower in the percentage of alloying element desired. The percentage desired is calculated and the required amount is then added. Common alloying elements include antimony, tin, arsenic, copper and nickel.

The refining processes most commonly employed are for the removal of copper and antimony to produce soft lead, and the removal of arsenic, copper and nickel to produce hard lead. For copper removal, the temperature of the molten lead is allowed to drop to 620 °F and sulphur is added. The mixture is then agitated and copper sulphide dross is skimmed off. Aluminum added to molten lead reacts preferentially with copper, antimony, and nickel to form complex compounds, which can also be skimmed from the surface of the metal. The antimony content can be reduced to about 0.02% by bubbling air through the molten lead. Further reduction can be achieved by adding a mixture of sodium nitrate and sodium hydroxide and skimming the resulting dross from the metal. Another common refining procedure is known as 'dry drossing' and consists of introducing sawdust into an agitated mass of molten metal. The resulting reaction forms carbon which aids in separating the globules of lead suspended in the dross, and reduces some of the lead oxide to elemental lead.

3.5 Storage Battery Manufacture (1)

The initial step in the manufacture of a lead-acid battery consists of melting an antimony-lead alloy in a crucible or kettle and pouring it into moulds containing grids. These grids form the framework of the battery plates, supplying mechanical strength for the active chemical ingredients and a conductive path for the electricity produced. Antimony alloy is required to produce strong, thin (0.05-0.25 in.) grids.

Lead compounds are then pressed onto the grid in the form of a paste, made by mixing powdered black oxide (a mixture of PbO , Pb), water and dilute sulphuric acid in a batch mixer. For negative plates, expanders such as barium sulphate, carbon black, or other organic materials are added to the mix to prevent plate shrinkage during use.

After the thick wet paste is formed into a plate around the lead-antimony grid, the plates are dried, cured, formed, and assembled into cells. 'Forming', the initial charging of a group of plates, is a process which oxidizes the metallic lead compound on the positive plates to lead peroxide and reduces the mixture on the negative plates to lead metal. This can be done either by charging a group of plates in a sulphuric acid bath before battery assembly, or by charging a finished battery which has been filled with sulphuric acid. The former method allows the battery to be shipped dry to dealers who add acid prior to purchase. The latter method is usually employed in producing batteries for new vehicles.

The final manufacturing steps begin with the stacking of several positive and negative plates, separated by cellulose insulators, into cells. Individual plates are then connected by welding or 'burning' a lead alloy bar across tabs on the plates. The battery top is sealed, and the battery posts are attached. Dry batteries are then packaged and shipped. The finished product contains about 20 lb of lead, approximately evenly divided between lead metal components and lead compounds on the plates.

3.6 Lead Compound Manufacture

3.6.1 Lead Oxides

3.6.1.1 Ball mill process. This method of lead oxide production involves the grinding of metallic lead by steel rods or balls. Oxidation is accelerated by the resulting heat of friction and by the heat generated in the exothermic oxidation reaction. Screening and further milling produce oxides of the desired particle size.

3.6.1.2 Barton process. Lead oxides for use in batteries can be produced by the Barton process which involves melting pig lead and rapidly agitating the molten metal in a furnace (4). This agitation, carried out at temperatures from 700-900 °F, is combined with baffles or a paddle rotating at about 150 rpm and atomizes the lead into droplets which are then oxidized by a forced stream of warm air. The oxide, which contains about 20% finely divided free lead, is separated from the air stream by bag filters, collected, and delivered by screw conveyor to storage.

Other lead oxides prepared by the Barton process are red lead (Pb_3O_4) used in the paint industry and yellow lead oxide (PbO) used in the paint and ink industries.

Because the process requires the use of a baghouse to collect the product, and no other contaminants are discharged, the bag filter serves the dual purpose of collecting the end product, and preventing discharge of dust particles to the atmosphere.

3.6.2 Lead Gasoline Additives. Two lead-based compounds, tetraethyl lead (TEL) and tetramethyl lead (TML), are added to gasoline to increase octane number.

The manufacture of TEL involves melting primary or secondary pig lead and mixing it with molten sodium to form a highly reactive lead-sodium alloy, containing about 10% sodium by weight (1). After solidification the alloy is ground to a powder in a nitrogen-induced atmosphere and charged to an autoclave at about 160 °F. Ethyl chloride is added over a period of a few hours and TEL is formed according to the reaction



The reaction products are taken from the autoclave and added to a water-filled batch still, where TEL is transported to a condenser by steam injected into the system. The remaining sludge in the still consists of lead salt, and some TEL. The TEL is vaporized by drying and the unreacted lead is separated from the sludge in a reverberatory furnace.

The steam distillation process produces a clear, colourless, oily TEL liquid which is washed in water and separated by gravity stratification. Different chemicals are blended with the purified TEL to produce various anti-knock compounds.

TML is produced following a similar procedure except that the sodium-lead alloy is reacted with methyl chloride in the presence of an aluminum chloride catalyst.

3.7 Metal Fabricating and Other Processes

There are many plants in Canada that use lead and lead alloys to produce a variety of metal goods. Common operations include the production of lead alloys in melting pots, the manufacture of collapsible tubes, ammunition, and plumbing goods, coating of electrical cables, and the casting, grinding and machining of such lead alloys as brasses and bronzes in foundries (1).

In the printing industry the hot letter press operation utilizes molten lead alloy prepared in pots. However, this process is carried out by only a few newspaper operators and its replacement by a non-emission-producing process is the long-term trend.

4 POLLUTION ASPECTS

The largest pollution source in either secondary lead processing or manufacturing is furnace operation. In order of magnitude particulate emissions from blast and reverberatory furnaces come first followed by those from pots or crucibles. Sources of particulate emissions, from secondary lead production and product manufacture are listed in production sequence as follows:

- | | |
|--|---|
| 1. Material Handling (Secondary lead operations) | (a) Outside storage |
| | (b) Sorting |
| | (c) Crushing |
| | (d) Conveyor transfer points |
| | (e) Conveying to metallurgical furnaces |
| | (f) Fugitive |
| 2. Secondary Lead Production | (a) Blast furnace operation |
| | (b) Reverberatory furnace operation |
| | (c) Pot or kettle operation |
| 3. Storage Battery Manufacture | (a) Lead milling |
| | (b) Mixing oxide pastes |
| | (c) Casting and lead burning operations |
| 4. Lead Compound Manufacture | (a) Lead milling |
| | (b) Barton process |
| | (c) Gasoline additive production |
| 5. Metal Fabricating | (a) Melting pots |
| | (b) Casting |
| | (c) Grinding and machining |

5 NATIONAL EMISSION INVENTORY DATA - PARTICULATES

5.1 Data Previously Published

Particulate emissions from lead production and product manufacture during 1970 amounted to 1526.8 and 106.5 tons respectively (1). Provincial breakdowns of these emissions are shown in Tables 6 and 7. It can be seen that secondary lead production accounted for 40.5 tons or 2.6% of the total emissions from primary and secondary lead production with the majority of emissions evolving from primary production sources such as mining, milling, smelting and refining operations. In manufacturing the highest lead emission source was gasoline additive production (64.5 tons), followed by secondary lead smelting (40.5 tons) and metal fabrication (38 tons).

Table 8 summarizes lead emissions in 1970 excluding primary production sources (1).

6 EMISSIONS

Data on both uncontrolled and controlled emission factors are summarized in Table 9 and cover various metallurgical furnaces as well as the major manufacturing processes.

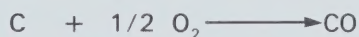
The factors in Table 9 have been estimated by various techniques including source testing, process material balances and engineering appraisals by the Environmental Protection Agency (EPA) of the United States (5). Canadian emission data were based on response to a questionnaire sent directly to Canadian manufacturers in 1970.

In addition to furnace operations, fugitive dust emissions can be a very important emission source if not properly controlled. Emissions occur from raw materials handling, especially outside-storage, which includes sorting, handling, crushing, as well as transfer within plant conveying systems.

6.1 Emissions from Secondary Lead and Remelting Operations

6.1.1 Blast Furnace Operation. The chemical reactions taking place in a lead blast furnace are:

- (a) Oxidation of coke for heat production according to the reaction



- (b) Reaction of carbon with lead dross according to



The principal air contaminants of the process are carbon monoxide from partial oxidation of the coke, and particulate matter entrained by the highly agitated gases passing through the furnace. The particulate matter consists primarily of lead oxide, together with some iron oxide and oxides of alloy metals. There will also be some sulphur dioxide and carbonaceous material (2).

TABLE 6 LEAD EMISSIONS FROM LEAD PRODUCTION, 1970 (1)

Province	Emissions (tons)					Total
	Mining	Milling	Smelting	Refining	Secondary	
Newfoundland	18.4	26.0	-	-	-	44.4
Prince Edward Island	-	-	-	-	-	-
Nova Scotia	1.2	1.7	-	-	-	2.9
New Brunswick	64.6	91.0	316.8	43.2	-	515.6
Quebec	2.0	2.8	-	-	4.4	9.2
Ontario	12.4	17.5	-	-	32.3	62.2
Manitoba	0.4	0.6	-	-	2.1	3.1
Saskatchewan	-	-	-	-	-	-
Alberta	-	-	-	-	1.7	1.7
British Columbia	110.5	155.9	141.0	19.3	-	426.7
Yukon Territory	68.0	95.5	-	-	-	163.5
Northwest Territories	123.5	174.0	-	-	-	297.5
TOTAL	401.0	565.0	457.8	62.5	40.5	1526.8

TABLE 7 LEAD EMISSIONS FROM MANUFACTURING, 1970 (1)

Province	Emissions (tons)					Total
	Storage batteries	Gasoline additives	Litharge	Metal fabrication		
Newfoundland	-	-	-	0.08		0.08
Prince Edward Island	-	-	-	-		-
Nova Scotia	0.12	-	-	0.27		0.39
New Brunswick	-	-	-	0.30		0.30
Quebec	0.48	-	-	8.74		9.22
Ontario	2.17	64.5	0.40	23.00		90.07
Manitoba	0.25	-	0.15	1.13		1.53
Saskatchewan	-	-	-	0.27		0.27
Alberta	0.32	-	-	1.63		1.95
British Columbia	0.09	-	-	2.58		2.67
Yukon and N.W.T.	-	-	-	-		-
TOTAL	3.43	64.5	0.55	38.00		106.48

TABLE 8 LEAD EMISSIONS FROM SECONDARY LEAD PRODUCTION AND MANUFACTURING, 1970

Industry	Emissions (tons/year)
Gasoline additives	64.5
Secondary lead	40.5
Metal fabrication	38
Storage batteries	3.43
Litharge	0.55

In addition to the particulate matter entrained by the gases flowing through the furnace, some vaporization of lead, antimony and other metals will occur with these metals condensing as metal fume in the exhaust system. The vapour pressure of these metals is a measure of their tendency to form vapours in a furnace. Table 10 illustrates this concentration of lead and antimony in equilibrium with flue gas from a blast furnace as a function of temperature.

In Canada, published data for two blast furnaces (1) reported an uncontrolled emission rate of 185 lb particulates/ton of lead produced while in the United States, EPA are in close agreement and have reported an uncontrolled rate of 190 lb/ton of lead produced.

6.1.2 Reverberatory Furnace Operation. Emissions from a reverberatory furnace are similar to those from a blast furnace and consist primarily of particulate matter containing a considerable portion of lead oxide and oxides of alloying metals (2). As in the blast furnace, lead, antimony and other metals will vaporize and condense as metal fume in the exhaust system. Also, oxides of sulphur may be introduced as lead sulphate or sulphuric acid when lead batteries are remelted. In addition, significant quantities of hydrocarbons are emitted from the partial combustion of plastics and oils. If polyvinyl chloride wire insulation is part of a furnace charge, combustion will release halogen acids. These are not only toxic but create objectionable odours when emitted to the atmosphere in significant quantities.

In Canada, published data for two reverberatory furnaces have reported an uncontrolled emission rate of 164 lb particulates/ton of secondary lead recovered while in the United States, EPA has published an emission rate of 130 lb/ton (Table 9).

6.1.3 Pot or Kettle Furnace Operation. Emissions from melting kettles are relatively low when compared to those from blast or reverberatory furnaces (5). Since the pot is used for many purposes, from melting pure scrap at just above the melting point of pure lead to refining the metal at higher temperatures, emissions vary in size and quantity. Canadian data indicates a range of emissions between 0.15 lb particulate lead/ton of lead processed and 0.4 lb/ton with a weighted factor of 0.26 lb/ton. This

TABLE 9 UNCONTROLLED AND CONTROLLED EMISSION FACTORS FOR VARIOUS LEAD PRODUCING AND CONSUMING PROCESSES (5)

Type of furnace or operation	Particulates			Sulphur oxides					
	Uncontrolled			Controlled			Uncontrolled		
	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT	kg/MT
Blast (cupola) furnace	190	95	2.3	1.15	90	45	0.8 ²	46 ³	0.4 ² 23 ³
Reverberatory furnace	130	65	1.6	0.8	85	42.5	-	-	-
Pot furnace ¹	0.8	0.4	neg	neg	-	-	-	-	-
Rotary reverberatory furnace	70	35	-	-	-	-	-	-	-
Battery ⁴	1.13	0.56	0.14	0.07	-	-	-	-	-
Litharge manufacture ⁴									
Barton process	24	12	0.12	0.06					
Gasoline manufacture	39.7	19.8	0.20	0.10					
Fabrication ⁴									
Melting and casting	4	2	0.04	0.02					

¹Emission factors expressed as units per unit weight of metal processed.

²With NaOH scrubber.

³With water spray chamber.

⁴Canadian data. Baghouse usual method of control.

TABLE 10 CALCULATED CONCENTRATIONS OF LEAD AND ANTIMONY FUME

Temperature °F	Lead		Antimony	
	Metal fume (ppm)	Grain loading (gr/scf)*	Metal fume (ppm)	Grain loading (gr/scf)
1150	23.69	.0895	78.25	.1737
1175	28.04	.1059	92.65	.2056
1200	33.01	.1247	109.13	.2422
1225	38.68	.1461	127.93	.2840
1250	45.11	.1704	149.27	.3313
1275	52.38	.1979	173.39	.3849
1300	60.56	.2288	200.57	.4452
1325	69.74	.2634	231.05	.5128

*Grains per standard cubic foot

is based on information received from 5 Canadian plants (1). In the United States, the EPA factor has been reported to be 0.8 lb particulate/ton indicating that American plants may utilize a higher degree of refinement resulting in a higher emission rate (Table 9). Emissions are in the form of lead oxides with smaller amounts of lead metal and lead sulphate particulates. Particle size was reported to be under 10 microns.

Further confirmation of these factors may be warranted by specific emission testing using approved federal standard test methods.

6.2 Storage Battery Manufacture

Atmospheric lead emissions from battery manufacture can result from several operations such as:

- (a) Milling of lead metal to produce lead oxide. Further details are provided in section 6.3.1.

- (b) Mixing of the oxide pastes which creates dust, particularly when pouring dry powder into the mixer. Some dusting also takes place in handling and stacking dried electrode plates.
- (c) Various casting and lead-burning operations which release lead fumes into the air.
- (d) Cleaning machine operation which prepares stacks of plates for welding also produces lead particulate emissions.

For paste mixing, the uncontrolled emission factor has been calculated to be 2 lb lead/ton of lead processed in compound form based on a questionnaire return from 12 Canadian plants. Emissions from casting and welding are similar to those from a pot or kettle operation and a factor of 0.26 lb/ton of lead has been applied. These figures have been halved when expressed in terms of total lead consumed because approximately half the lead used by battery manufacturers is in lead-metal form and half in compound form, thus the total uncontrolled emission factor becomes 1.13 lb particulate lead/ton of lead produced (Table 9). Emissions consist of lead oxide, lead sulphate, and lead metal particles from paste-mixing operations. Total lead emissions from battery manufacture in Canada in 1970 have been calculated at 3.43 tons (1).

6.3 Lead Compound Manufacture

6.3.1 Gasoline Additives. Atmospheric lead emissions in the manufacture of tetraethyl and tetramethyl lead, consist of lead particulates from melting and recovering the lead and organic lead vapours from the manufacture, recovery, and storage of alkyl lead compounds. An uncontrolled emission factor of 39.1 lb lead/ton has been calculated and if building ventilation and storage tanks are considered, this becomes 39.7 lb/ton consumed. The industry has reported an overall control of 83% using cyclones and scrubbers resulting in a total emission of 64.5 tons in 1970 (1).

6.3.2 Metal Fabricating. For operations involving casting and machining an uncontrolled emission factor of 4 lb lead/ton of lead processed has been applied. It should be noted that this figure is based on a minimal response to the questionnaire in the 1970 study. An additional 7 lb/ton has been used to account for grinding losses and applies generally to lead-containing copper alloys, consumed in foundries where most grinding takes place. Since pot or crucible melting is also used in metal fabricating, an additional uncontrolled emission factor of 0.26 lb/ton of lead consumed has been applied. Emissions are in the form of lead oxides, and metallic dusts from melting, casting and fabrication. Emissions in 1970, based on these factors, totalled 38 tons (1).

7 CONTROL METHODS

7.1 General

Lead emissions can be minimized by the application of conventional control measures together with the use of sound engineering principles and good housekeeping practices (6). Control methods in the industry, to date, have been based on technology which can limit emissions to a high

degree. This technology should be applied to all emission sources within a plant boundary including raw material storage as well as handling and conveying systems.

7.2 Raw Material Handling and Storage for Secondary Smelters

Emissions to the atmosphere can be reduced by enclosing stockpiles to eliminate dust entering the atmosphere. Practically, this involves keeping stockpiles inside a building equipped with a hooding system which captures dust from the piles and passes it through a collection device before exhausting to the atmosphere. This is applicable for any materials handling or processing operation which may cause particulate emissions such as crushing, sorting and conveyor transfer. Conventional collection devices such as cyclones, fabric filters, or scrubbers are the usual methods of control.

7.3 Emission Control for Metallurgical Furnaces

7.3.1 Blast Furnaces (Cupola). Emissions from blast furnaces can be contained with conventional control equipment such as fabric filters or high energy scrubbers.

When fabric filters are used to control blast furnace emissions, they are normally preceded by a cooling tower and an afterburner as shown in Figure 3. The afterburner incinerates smoke and eliminates carbon monoxide. It should be designed to allow a residence time of approximately 0.5 seconds for the gases leaving the smelting section of the furnace. Excessive air leakage inward at the charging door will increase fuel requirements for the afterburner section and should be eliminated or substantially reduced.

The fume loading leaving the afterburner section may be extremely high, as much as 10% of the material charged. A typical value quoted is 7% of the total charged. Gases leaving the cupola are normally cooled by infiltration of ambient air. Special care is needed in designing the system to prevent ignition of the filter bags in the event that the ventilating fan stops or the exit temperature becomes excessive, especially during 'burn down' at the end of a run.

With wet scrubbers, it is possible to limit the size of the scrubber by using water for quenching rather than infiltrated air. Quenching can be introduced immediately following the afterburner section of the cupola. The duct can be designed for a relatively low gas volume and should be made of corrosion-resistant material such as stainless steel or refractory-lined carbon steel.

Blast furnaces checked by EPA in the United States for exit grain loading averaged between 0.009 and 0.013 gr/scf when the following control equipment was used:

- Afterburner and baghouse
- Afterburner, baghouse and venturi scrubber
- Venturi scrubber

Production rates for the furnaces tested varied between 20 and 80 tons per day (7).

Other tests on three blast furnaces, controlled by an afterburner and a baghouse, averaged respectively, 0.001, 0.005 and 0.012 gr/scf. These data show that a high degree of containment varying between 99.0 and 99.5% is attainable with this type of control equipment.

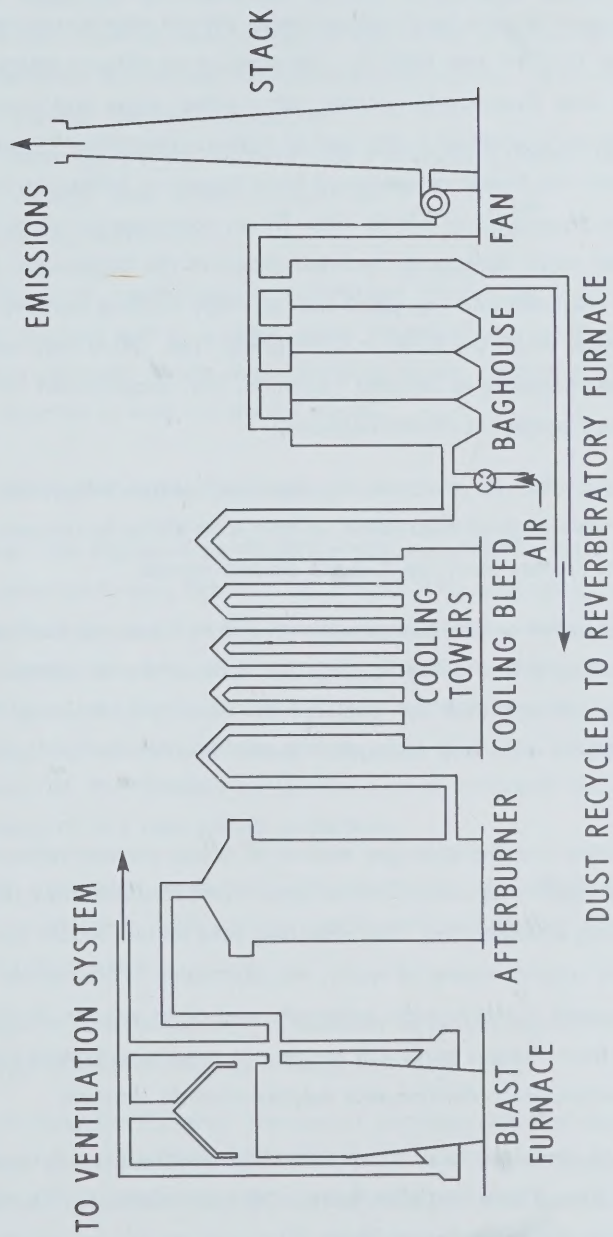


FIGURE 3 CONTROLLED LEAD BLAST FURNACE, AFTERBURNER AND BAGHOUSE

7.3.2 Reverberatory Furnaces. Emissions from the reverberatory furnace (Figure 2) can also be controlled to a high degree (over 99%) by using conventional equipment such as fabric filters or high energy scrubbers. However, an afterburner may not be needed since there is usually sufficient air and temperature to incinerate carbon monoxide and hydrocarbons. Where afterburners are used, a luminous flame usually operates between 1200 °F and 1500 °F. The afterburner effluent gases are normally cooled to a temperature of 250 °F or less. Evaporative cooling with a water spray and mixing with ambient air are practiced, but a more successful method is the use of radiant convection U-tube heat exchangers. Care should be taken to prevent baghouse temperature from dropping below the water or acid vapour dew point, which may result in hydrolysis of halide salts. Direct condensation of hydrochloric, sulphuric or hydrofluoric acids could then occur damaging the fabric filters in the baghouses. It may be necessary to have a baghouse both fully insulated and equipped with standby heating facilities to ensure minimum condensation, even during periods when the furnace is not being fired. Other precautions include coating the baghouse with epoxy-type materials to prevent corrosion. For uncontrolled temperature surges, a bypass damper may be required upstream of the baghouse.

Wet scrubbers can also be successfully used to control emissions from reverberatory furnaces. The most important advantage of a scrubber system is its ability to remove corrosive gases and mists as well as fine particulate matter from the furnace effluent gases.

In some cases, corrosive or noxious gases evolve from materials such as polyvinyl chloride (PVC) or Teflon in the scrap charged to the furnace. Hydrochloric acid and organic vapours will evolve from PVC-coated wire and hydrofluoric acid can evolve from material containing Teflon. To overcome these excessive gaseous emissions, a packed absorption tower, in addition to a scrubber or baghouse, may be necessary.

Where battery plates are the principal source of scrap, concentrations of sulphur dioxide (SO_2) between 2000 and 5000 ppm may occur. In this case, a wet scrubber may be required to remove SO_2 from the gas stream leaving a fabric filter. The resulting acid waters would have to be neutralized prior to discharge into sewers or natural bodies of water. An alternative to acid water neutralization is the use of an alkaline scrubbing system. Caustic soda, soda ash, and other soluble alkaline materials can be used to remove sulphur oxides from the gas stream. A single wet scrubbing system could also be installed which would carry out both particulate collection and sulphur dioxide removal.

EPA test results for emissions from three controlled reverberatory furnaces averaged 0.003 grains per dry standard cubic foot. These furnaces were production-rated at 20, 40 and 65 tons/day and all were equipped with high efficiency fabric filters (7).

7.3.3 Pot or Kettle Furnaces. High efficiency (over 99.5%) scrubbers and fabric filters are being utilized in well-controlled plants using pots for melting, refining or alloying purposes. Observations of nine smelters in the United States controlled by these devices have shown visible emissions of less than 10% opacity (7). In some plants, the same collection devices used to control emissions from reverberatory furnaces and blast furnaces are used to collect emissions from pot furnaces. Where arsenic is used as an alloying element, it is imperative that the melting kettle be completely hooded and that fumes be allowed

to condense in a cooling unit prior to filtering in a high efficiency filtering device before the exhaust gas is emitted to the atmosphere.

7.3.4 Other Sources. Conventional control equipment including cyclones, high efficiency scrubbers and fabric filters are the usual means of controlling emissions from remelting, milling, handling, and burning operations for the various manufacturing processes. This would include the following:

- storage battery production
- lead compound manufacture including gasoline additives, litharge and other compounds
- metal fabrication

In addition to using control technology to contain dust and fumes from the various emission-producing sources within a plant, good housekeeping is an essential method of preventing fugitive dust buildup. Canopy hoods over charging doors, launder's ladles and pouring stations are considered normal practice in well-controlled plants.

7.4 Evaluation of Control Technology

7.4.1 General. The degree of particulate emission control for blast furnaces, reverberatory and pot furnaces has been reported to vary between 98 and 99.5%, depending on when control equipment was installed. Current technology, such as high energy scrubbers and fabric filters, achieves efficiencies over 99.5%. Secondary lead manufacturing industries can also utilize high efficiency equipment such as combinations of cyclones and baghouses or cyclones and high energy scrubbers. Control efficiencies of 99.5% have been reported for battery plants. The goal for all secondary lead producers and manufacturers should be the efficient containment of all emission and fugitive dust sources with all captured dust disposed of in a non-polluting manner.

Carbon monoxide emissions can be easily controlled by the use of well-designed afterburners. The cost of these units can be significantly reduced by eliminating excessive air seepage through furnace charging doors.

For sulphur dioxide removal in addition to particulate control, best practicable technology would be high energy scrubbers utilizing alkaline solutions.

7.4.2 Cost of Pollution Control. The cost of installing pollution control equipment for a secondary lead smelter has been calculated to be approximately 8% of the total capital cost (8). For a new smelter this could vary between \$250 000 for a 30 ton/day to \$360 000 for a 50 ton/day smelter. Part of such an expenditure, however, would be recovered in efficient, economic operation of the plant and minimal raw material loss. Captured lead dust can be pugged and recycled in the blast or reverberatory furnace. As a result, the percentage of capital cost required solely for pollution control could be considerably less than that shown above.

Operating costs for pollution control equipment vary from plant to plant. Higher costs can be expected in older plants where additional control equipment is added to satisfy more stringent local requirements. In new, well-designed plants incorporating latest process improvements, these operating

costs can be reduced by the establishment of a good maintenance program. Reliable figures for operating costs are not available.

7.4.3 Control Technology. Control technology currently being used by some segments of the industry has been described in Section 7.3. The emission factors using this control technology are summarized in Table 9 and are expressed in terms of units per unit weight of metal processed. If this control technology was applied throughout the industry the expected emission reduction would be that shown in Table 11. The overall reduction would amount to 85.2% or 125.18 tons.

TABLE 11 ESTIMATED PARTICULATE EMISSIONS FOR THE CANADIAN SECONDARY LEAD SMELTER AND ALLIED INDUSTRIES IF BEST CONTROL TECHNOLOGY WERE USED

Source	Emissions (tons/year 1970) (1)	Emissions if BCT were used (estimated)	% Reduction
Gasoline additives	64.5	2.1	
Secondary lead	40.5	11.7	71
Metal fabrication	38	5.7	85
Storage batteries	3.43	1.7	50.4
Litharge	0.55	0.6	
TOTAL	146.98	21.8	85.2

REFERENCES

1. Air Pollution Control Directorate, ***National Inventory of Sources and Emissions of Lead (1970)***, Environmental Protection Service, Department of the Environment, Ottawa, Ontario, Internal Report APCD 73-7 (Nov. 1973).
2. Hardison, L.C., and Herington, H.R., ***Study of Technical and Cost Information for Gas Cleaning in the Lime and Secondary Non-Ferrous Metallurgical Industries***, Industrial Gas Cleaning Institute, U.S. Environmental Protection Agency, APTD-0642 (1970).
3. Gauvin, M., "Antimony", ***Canadian Minerals Yearbook 1971***, Preprint No. 3, Department of Energy, Mines and Resources, Ottawa, Ontario (1972).
4. Danielson, J.A., (ed.), ***Air Pollution Engineering Manual***, Department of Health, Education, and Welfare, Public Health Service, National Center for Air Pollution Control, Cincinnati, Ohio, PHS Publication No. 999-AP-40 (1967).
5. U.S. Environmental Protection Agency, ***Compilation of Air Pollutant Emission Factors***, (Revised) (Feb. 1972).
6. Mayers, M.R., ***Study of Fundamentals in Prevention of Lead Poisoning in Industry***, Division of Industrial Hygiene, Department of Labour, State of New York (1943).
7. Office of Air Quality Planning and Standards, ***New Source Performance Standards, Group II, Vol. I***, U.S. Environmental Protection Agency, Technical Report No. 10 (Jan. 1973).
8. Air Pollution Control Directorate, ***Internal Document***, Environmental Protection Service, Department of the Environment, (Oct. 16, 1974).

BIBLIOGRAPHY

- Associate Committee on Scientific Criteria for Environmental Quality, *Lead in the Canadian Environment*, National Research Council of Canada (Dec. 1973).
- Bainbridge, C.A., "Fume Control and Recovery in Lead Smelting Furnaces", *Chem. Proc. Eng.*, **41** 344-351 (Aug. 1960).
- Berg, B.A., and Lenz, C., M.D., "Environmental and Clinical Control of Lead Exposure in a Non-Ferrous Foundry", *Am. Ind. Hyg. Assoc. J.* (March-April 1967).
- Blythe, D.J., "Lead Smelting Plant Control Air Emissions", *Environmental Science and Technology*, **5** (4), 304-305 (April 1971).
- Council of Planning Librarians, *Lead in the Urban Environment. A Selected Bibliography* #437, Monticello, Illinois.
- Davis, W.E., and Associates, *Emission Study of Industrial Sources of Lead Air Pollutants, 1970*, U.S. Environmental Protection Agency (April 1973) (NTIS PB 223652).
- Halpern, H.J., M.D., and Reichenbach, G.S., "Engineering and Medical Control of Lead Exposure in Patent Annealing and Galvanizing of Wire", *Industrial Hygiene Quarterly*.
- Hattawax, J.S., "Evaluation and Control of Lead Exposure in Power Metallurgy Operations", *Am. Ind. Hyg. Assoc. J.* (Dec. 1958).
- Horn, John, Ph. D., Letters and Reports, University of Western Ontario (1974).
- Jones, H.R., *Pollution Control in the Non-Ferrous Metals Industry*, Noyes Data Corp., Park Ridge, N.J. (1972).
- "Lead and Arsenic Report, Informative Report No. 1", *J. Air Pollut. Control Assoc.*, **10** (4), 296 (Aug. 1960).
- Leroux, J. et al. *Lead Hazard at the Plant of Surette Battery Co. Ltd., Springhill, Nova Scotia*, Department of National Health and Welfare, Report OH 71-101 (Jan. 21, 1971).
- Office of Air Quality Planning and Standards, "New Source Performance Standards, Group II, Secondary Lead Smelters and Refineries, Technical Report No. 10, Vol. 2, U.S. Environmental Protection Agency (June 1973).
- Ontario Working Committee on Lead Pollution, *Interim Report on Lead in the Environment in the Vicinity of Secondary Lead Smelters in Metropolitan Toronto*, (Aug. 1974).
- Patterson, C., *Report Concerning Public Health Hazards of Industrial Lead Pollution*, Division of Geological and Planetary Sciences, Cal. Inst. of Techn. 90041 (May 1974).
- Quarles, J.R., Jr., "Opening Statement, Environmental Protection Agency Press Conference on Reducing Lead in Gasoline" (Nov. 1973).

Rispler, L., *Lead Hazard Survey, Surette Battery Co. Ltd., Springhill, Nova Scotia*, Department of National Health and Welfare, Ottawa (Aug. 1966).

Ross, C.R., *Lead Hazards at Surette Battery Co. Ltd., Springhill, Nova Scotia, Aug. 1969, Report # 2*, Department of National Health and Welfare, Ottawa (Sept. 1969).

Stockinger, H.E., "Recent History of Lead Exposure in U.S. Industry, 1935-1965", *Symposium on Environmental Lead Contamination*, (Dec. 13-15, 1968), Public Health Service, Washington D.C., (March 1966) (NTIS PB 198104).

Submission to the Government of Ontario on the Control of Industrial Lead Pollution. Submitted by the Labour Council of Metropolitan Toronto, South King Residents Association, Portland Area Residents B.R.E.M.M. Residents Association, Volunteer Residents Committee (Dovercourt Park, Dufferin-Davenport, Wallace-Emerson Residents Association) (March 1974).

U.S. Environmental Protection Agency, *Air Pollution Aspects of Emission Sources: Primary Lead Production, A Bibliography with Abstracts*, (June 1973) (NTIS PB 224869).

U.S. Environmental Protection Agency, "Background Information for New Source Performance Standards Asphalt Plants, Petroleum Refineries, Storage Vessels, Secondary Lead Smelters and Refineries, Brass or Bronze Ingot Production Plants, Iron and Steel Plants, Sewage Treatment Plants", (Feb. 1974).

Zykoua, A.S., "Contamination of Atmospheric Air with Lead and its Effect on Population Health", *Gigiena I. Sanit.*, No. 2, 12-17 (1975).

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